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Blood lead level and cognitive performance in Ukrainian schoolchildren

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Background. Modern systematic review and meta-analysis of case-control studies demonstrate the large effect of lead exposure on IQ test scores in children under 12 years. The World Health Organization estimate that lead exposure causes 30% of the global burden of idiopathic intellectual disability. In this regard, in the most developed countries, for example, the United States, there are special government programs, International Lead Poisoning Prevention Weeks, which present an opportunity to initiate long-overdue reforms. In Ukraine, there are no state programs of such a scale as in the United States. Research on the study and limitation of the ecopathological effect of lead on the psychosomatic state of Ukrainian schoolchildren is still rare.

The aim of this study was to evaluate the effect of blood lead levels on cognitive sphere indexes in urban schoolchildren resident in Odesa, Ukraine.

Materials and Methods. 92 children of random sample were examined, aged 7 to 15 years. Determination of lead was carried out in heparinized venous blood by the method of atomic absorption spectrometry with electrothermal atomization. According to blood lead level, the children were divided into 4 groups: 1) up to 49 µg/l, n = 57; 2) from 50 to 99 µg/l, n = 16; 3) from 100 to149 µg/l, n = 14; 4) more than 150 µg/l, n = 5. The groups were homogeneous in terms of such indicators as age, sex of children, diseases they suffered, education and social position of parents, family wealth, peculiarities of pregnancy and childbirth by a given child in the mother. Indicators of the cognitive sphere were determined according to the methods recommended for research in children aged 7 to 15 years. The control was the first group of children.

Results. The deviation rate from the optimal level of figure recognition in children of the second group (1.38±0.27) and the third group (1.43±0.27) was significantly higher than in children of the first group (0.73±0.12 points). The number of correctly reproduced images by children of the third group (7.86± 0.51) and the fourth group (7.00±0.89) was significantly less than that of children of the first group (9.12±0.41). Both indicators reflect the state of short-term memory. The number of words memorized by Luria's method, reproduced after 1 hour, was significantly less in schoolchildren of the second group (7.87±0.37), the third group (6.50±0.57), the fourth group (6.20±1.07) than in schoolchildren of the first group (8.77±0.14). This indicator reflects the state of long-term memory. The concentration of attention on the Bourdon test in children of the third group (85.6±18.4 c.u.) was significantly lower than in children of the first group (126.9±12.8 c.u.). Children of the same group worked longer with the Gorbov table (283.0±22.6 s) compared to children of the first group (221.1±9.2 s). Schoolchildren of the second and third groups showed worse results of attention tests compared to the first group, such as the indicator of switching attention on the Bourdon test (respectively 67.64±4.06% and 71.84±3.17% vs. 83.34±2.14%), the number of errors when working with the Gorbov table (respectively 2.87±0.54 and 3.00±0.64 against 1.16±0.14), the time of switching attention (respectively 131.8±12.3 s and 146.9±17.5 s versus 101.7±6.3 s). In addition, the number of uncorrected errors in the Halperin, Kabylitskaya test was higher in children of the third group (4.92±0.64) and the fourth group (4.80±0.80) than in children of the first group (2.87±0.26).

Conclusion. Increasing the level of lead in the blood of Ukrainian schoolchildren negatively

affects their cognitive sphere, impairing short-term and long-term memory, reducing concentration, and slowing down the rate of switching attention.

BLOOD LEAD LEVEL AND COGNITIVE PERFORMANCE IN UKRAINIAN SCHOOLCHILDREN

BACKGROUND. Centuries of human activities, particularly housing and transportation practices, dispersed hundreds of millions of tons of lead into our urban areas [1]. Lead poisoning is among the most significant factors affecting the growth and functional development of children [2]. Especially adverse effects of lead on the mental function. The new systematic review and meta-analysis of case-control studies demonstrate the large effect of lead exposure on IQ test scores in children under 12 years [3]. The World Health Organization estimate that lead exposure causes 30% of the global burden of idiopathic intellectual disability [4]. In this regard, in the most developed countries, for example, the United States, there are special government programs, International Lead Poisoning Prevention Weeks, which present an opportunity to initiate long-overdue reforms [5]. In Ukraine, there are no state programs of such a scale as in the United States. Research on the study and limitation of the ecopathological effect of lead on the psychosomatic state of Ukrainian schoolchildren is still rare.

The aim of this study was to evaluate the effect of blood lead levels on cognitive sphere indexes in urban schoolchildren resident in Odesa, Ukraine.

MATERIALS AND METHODS. The study included 92 random children aged from 7 to 15 years. The inclusion of children in the study was carried out subject to the informed consent of the parents of the children after providing detailed information on the procedure and purpose of the work.

Determination of lead was carried out in heparinized venous blood by the method of atomic absorption spectrometry with electrothermal atomization after wet mineralization of samples. According to blood lead level, the children were divided into 4 groups: 1) up to 49 μg/l, n = 57; 2) from 50 to 99 μg/l, n = 16; 3) from 100 to149 μg/l, n = 14; 4) more than 150 μg/l, n = 5. The first group was a control. It is known that not only the blood lead level can affect the studied indicators, but also, first, age, sex of children, diseases they suffered, education and social position of parents, family wealth, peculiarities of pregnancy and childbirth by a given child in the mother, can affect. To establish homogeneity according to these factors of the selected groups of children, the χ^2 test was calculated. This method, which also called "analysis of proportions", allows to provide statistically evenness or unevenness of the distribution of certain features in groups. Rating χ^2 calculations showed that the groups were homogeneous, hence the differences in the cognitive sphere data could be explained in this case only by a different blood lead level.

Indicators of the cognitive sphere were determined according to the methods recommended for study in children aged 7 to 15 years [6]. 4 groups of tests were used: a – for memory research; b – for attention research; c – for the study of thinking; g – for the study of personality traits. Studies of short-term memory were carried out on the recognition of figures and on the memorization of numbers and images. The assessment of the level of recognition of figures was carried out by deviation from the optimal value (1 unit) and expressed in points: 0 points – there was no deviation; 1 point – deviation up to 0.5 units; 2 points – deviation from 0.51 up to 1.00; 3 points – deviation of 1.01 or more. Long-term memory was evaluated by memorizing 10 words according to the method of A.R.Luria. Investigating attention, we used a proofreading test (Bourdon test), Schulte tables, and Gorbov's black and red table. The switching attention index (SAI) in the Bourdon test was calculated by the formula: SAI = 100 – $L_{er.}$ / $L_{tot.}$ x 100, where $L_{er.}$ – the number of erroneously processed lines; $L_{tot.}$ – the total number of lines in this task. The results were expressed as a

percentage. The time of switching attention was defined as the difference between the time of work with the Gorbov table and the total time of work with the first and second Schulte's tables. In children after 9 years, the test of P.Y. Halperin and S.L. Kabylitskaya was also performed. To study *thinking* in children after 10 years, a test to find simple analogies was used. Studies of personality traits were conducted in children after 10 years using the Eysenck questionnaire.

The obtained data were subjected to statistical processing using the t-test. Reliable were considered differences in $p < 0,05$.

RESULTS AND DISCUSSION. The data obtained because of the study are presented in the table.

Table. Indicators of the cognitive sphere in children of different groups

Indicators \ groups	1st group	2nd group	3rd group	4th group
Deviations from the optimal level of recognition of figures, points	0.73±0.12	1.38±0.27*	1.43±0.27*	1.40±0.51
Number of correctly reproduced numbers	3.75±0.23	3.67±0.20	3.57±0.31	3.80±0.37
Number of correctly rendered images	9.12±0.41	8.19±0.54	7.86±0.51*	7.00±0.89*
The number of words memorized by the method of Luria, reproduced after 1 hour	8.77±0.14	7.87±0.37*	6.50±0.57*	6.20±1.07*
Concentration on the Bourdon test, c.u.	126.9±12.8	117.1±21.1	85.6±18.4*	99.8±14.9
Attention switching rate according to the Bourdon test, %	83.34±2.14	67.64±4.06*	71.84±3.17*	71.17±6.43
Average working time with Schulte tables, seconds	58.38±3.41	60.33±5.38	64.46±6.94	63.56±4.43
Working hours with the Gorbov table, seconds	221.1±9.2	243.9±18.7	283.0±22.6*	282.0±38.8
Number of errors when working with the Gorbov table	1.16±0.14	2.87±0.54*	3.00±0.64*	3.40±1.33
Time to switch attention, seconds	101.7±6.3	131.8±12.3*	146.9±17.5*	150.8±27.2
Number of uncorrected errors in the test Galperin, Kabylitskaya	2.87±0.26(n=53)	3.21±0.42(n=14)	4.92±0.64*(n=12)	4.80±0.80*(n=5)
Number of errors in finding analogies	2.60±0.40(n=52)	2.50±0.49(n=14)	2.91±0.68(n=11)	3.25±0.85(n=4)

Note. * - The difference is significant ($p<0.05$) with the indicators of the first group.

As we can see from the table, the greatest number of reliable differences with control was observed in the third group of children, where the lead content in the blood ranged from 100 to 149 μg/l. Relatively fewer reliable changes in the fourth group can be explained by its small number, because of which the pronounced trends could not achieve a degree of reliability in statistical processing.

Analysis of the test for the study of *personality traits* (Eysenck's questionnaire) did not reveal significant differences between groups of children on the scales of intro- and extraversion and

neuroticism. Therefore, its results are not included in the table.

Analysis of the results of memory tests showed that the level of recognition in children of the second and third groups differed from the optimal value more than in children of the first, control group. At the same time, the number of correctly reproduced images by schoolchildren of the third and fourth groups was significantly less than that of children of the first group. This indicates a deterioration in *short-term memory* [6] in children with higher concentrations of lead in the blood, compared to those in which these concentrations were the lowest. A significant decrease in the number of words memorized by the method of A.R.Luria, reproduced after 1 hour, was found in children of 2-4 groups. This indicates a relative deterioration in *long-term memory* [6] in children with higher concentrations of lead in the blood.

Analysis of the indicators of tests for attention research also revealed reliable differences between different groups of children. Thus, the *concentration of attention* on the Bourdon test was significantly worse in children of the third group than in children of the first group. The attention *switching* rate was lower in the same group as well as in the second group, compared to the rate in the first group. The children of the third group worked reliably longer with the Gorbov table, while making more mistakes. The latter indicator was reliably changed in the second group of children. Attention switching time determined using the Gorbov table and Schulte tables, also significantly increased in children of groups 2-4 compared to the same indicator of the first group. This may indicate a relative decrease in the mobility of the nervous system processes [6] in children with an increase in lead content in the body. The number of uncorrected errors in the test of P.Y. Galperin and S.L. Kabylitskaya was greater in children of the third and fourth groups. This indicates a certain decrease in the *level of attention* [6] in these children compared to children of the first group.

Analysis of the test for the *study of thinking* showed that in all the children examined, logical forms of thinking prevailed over visual ones. However, the number of errors in finding analogies tended to increase with increasing levels of lead in the blood. This indicates less resilience, greater vulnerability in the thinking process and greater fatigue [6] in these children.

Our study findings confirmed the previously established association of blood lead levels with cognitive impairment in children. Including the systematic review and meta-analysis of case-control studies were provided by investigations from different countries over the world. This study also demonstrated that the concentration of lead exposure had a large effect on mental function in children under 12 years [3].

CONCLUSION. Increasing the level of lead in the blood of Ukrainian schoolchildren negatively affects their cognitive sphere, impairing short-term and long-term memory, reducing concentration of attention, and slowing down its switching.

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